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Biodynamic Assessment of Pilot Knee-Board Configurations During Simulated T-38 Catapult Acceleration

Mr. Chris Perry
Mr. Chris Burneka
Mr. Joseph Strzelecki
Warfighter Interface Division

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Interim Report

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711 HUMAN PERFORMANCE WING,
HUMAN EFFECTIVENESS DIRECTORATE,
WRIGHT-PATTERSON AIR FORCE BASE, OH 45433
AIR FORCE MATERIEL COMMAND
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//signed//
CHRIS BURNEKA
Work Unit Manager
Applied Neuroscience Branch

//signed//
SCOTT M. GALSTER
Chief, Applied Neuroscience Branch
Warfighter Interface Division

//signed//
WILLIAM E. RUSSELL
Chief, Warfighter Interface Division
Human Effectiveness Directorate
711 Human Performance Wing
Air Force Research Laboratory

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14. ABSTRACT The Aircrew Biodynamics and Protection (ABP) Team of AFRL (711 HPW/RHCPT) and their in-house technical support contractor, Infoscitex, conducted a short series of tests to support an objective analysis of determining injury risk to a pilot ejecting from a T-38 with current or proposed kneeboard technology. This effort was initiated to provide data to assist with ejection injury analysis in order to assess if there is additional risk associated with the proposed electronic kneeboard configuration compared to the paper kneeboard configuration. The proposed kneeboard configuration consisted of an Apple iPad Mini with a shock case. The T-38C ejection pulse was simulated using the Vertical Deceleration Tower (VDT) set-up with a Martin Baker Mk series ejection seat, and the pulse characteristics were determined based on measured seat pan accelerations recorded during the seat testing with both small and large manikins. The USAF currently accepts up to a 5% risk of injury to the spine during the catapult phase of ejection; therefore, this injury risk was also used for the kneeboard configuration comparisons. Data from the test series indicated the risk of using either kneeboard configuration (paper or EFB) was below 5% regardless of the size of the occupant. In general, the data indicated that larger occupants were at a lower risk than the small occupants with the larger occupants having a risk of femur fracture in the 2 to 3% range, and the small occupants having a risk of femur fracture in the 3.5 to 4.5% range. This was most likely due to the small occupants being exposed to a greater catapult acceleration based on the current seat installed in the aircraft. The observational data indicated that the current Velcro strap and the Buckle Clip Strap may not sufficiently support either kneeboard configuration regardless of occupant size; however, the larger occupant had issues with both configuration in the this test series.

15. SUBJECT TERMS Pilot training, USAF Training Aircraft, T-38 ejection seat, Electronic Flight Bag (EFB), Kneeboard, Impact Test, Vertical Deceleration Tower, Femur Load, Injury Risk

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Table of Contents

LIST OF FIGURES

LIST OF TABLES

1.0 OVERVIEW

The Aircrew Biodynamics and Protection (ABP) Team of AFRL (711 HPW/RHCPT) and their in-house technical support contractor, Infoscitex, conducted a short series of tests to support an objective analysis of determining injury risk to a pilot ejecting from a T-38 with current or proposed kneeboard technology. This effort was initiated to provide data to assist with ejection injury analysis in order to assess if there is additional risk associated with the proposed electronic kneeboard configuration compared to the paper kneeboard configuration. The proposed kneeboard configuration consisted of an Apple iPad Mini with a shock case. The T-38C ejection pulse was simulated using the Vertical Deceleration Tower (VDT) set-up with a Martin Baker Mk series ejection seat, and the pulse characteristics were determined based on measured seat pan accelerations recorded during the seat testing with both small and large manikins.

A Joint Primary Aircraft Training System (JPATS) Case 6 large male manikin (or Large Anthropometric Research Dummy, LARD), and a JPATS Case 1 small female manikin, were used in this program to simulate human response, and to evaluate risk bask on occupant size. Data collection on the VDT consisted of VDT carriage accelerations, ejection seat accelerations measured at the intersection of the seat back and seat pan planes, restraint loads, manikin accelerations, and manikin femur loads and moments.

2.0 BACKGROUND

The 12th Flying Training Wing (12 FTW) at JBSA Randolph, TX, per a request from HQ AETC/A3 (Flight Training Division), is currently investigating the risk of using Electronic Flight Bags (EFB) in ejection capable aircraft, and in particular, the T-38C and the T-6. EFB's have been in use in commercial aviation and other Air Force commands for years, and there is an increasing effort to provide this equipment for all pilots in all USAF training aircraft. Specifically, the 12 FTW is seeking approval for a T-1, T-38C, and T-6 EFB pilot program as a first step towards implementation of EFBs in all Standardized Undergraduate Pilot Training (SUPT) aircraft. Initial concerns are to determine what research is required to support or reject the safety of the EFB's in ejection seat aircraft such as the T-6 and the T-38C.

Currently, the only operational USAF ejection aircraft flying with EFBs attached to their legs are the 394th CTS T-38As at Whiteman AFB. Since there is no current research, or laboratory test data to support a risk analysis, this unit is operating under command assumed risk per their AFGSCI 11-270. AETC's 12 FTW is seeking an assessment to support the hypothesis that the EFB implementation risk is equal to or less than the current risk level assumed when flying with the approved USAF configuration for kneeboard/in-flight guide/checklist attached to a pilot's leg.

In support of the proposed pilot program, the 711 HPW at AFRL had been asked to provide information on ejection injury analysis in order to assess if there is additional risk involved with using EFB's. Ejection injury risk consists of comparison of the current authorized equipment (kneeboard, with paper in-flight guide and paper checklist, approximately 3.0 lbs) versus the proposed EFB configuration (Apple iPad Mini with OtterBox Case and leg strap, approximately 1.5 lbs).

3.0 OBJECTIVES

The primary purpose of the effort was to determine the risk of injury to the occupant during the catapult phase of ejection with the current paper in-flight guide and checklist kneeboard configuration versus the proposed EFB configuration strapped to the occupant's left leg. The probability of injury was determined by inputting the measured femur loads from the small and large instrumented manikins into a probability equation. Risk assessment focused on comparing the calculated femur injury probability values to an accepted probability risk value.

The critical issues to be addressed by this test program were: (1) Does the proposed electronic kneeboard configuration increase the probability of femur fracture compared to the probability with the current paper kneeboard configuration?; (2) Does the probability of femur fracture with the electronic kneeboard configuration change based on the size of the occupant?; (3) Does the probability of femur fracture with the electronic kneeboard configuration fall within acceptable USAF risk of injury values?

4.0 TEST FACILITY AND EQUIPMENT

The test method used to evaluate the kneeboard configurations during an ejection was to conduct a series of tests on the Vertical Deceleration Tower (VDT). The VDT facility was used to provide a simulation of the ejection seat catapult acceleration.

4.1 Vertical Deceleration Tower

The 711th HPW VDT located in Bldg. 824, WPAFB OH was used for all the impact tests conducted for this test effort. The VDT facility is composed of a 50 ft. vertical tower composed of two vertical steel rails and a drop carriage (Figure 1). The carriage is allowed to enter a free-fall state (guided by the rails) from a pre-determined drop height. A plunger mounted on the rear of the carriage is guided into a cylinder filled with water located at the base and between the vertical rails. A +Gz acceleration pulse is produced when water is displaced from the cylinder by the carriage-mounted plunger. The pulse shape is controlled by varying the drop height, which determines the peak G-level, and by varying the shape of the plunger, which determines the rise time of the pulse. A Mk series ejection seat was mounted in a +z-axis impact orientation on the front vertical surface of the VDT drop carriage (Figure 2).

Figure 1. 711th HPW VDT Tower Facility used for Kneeboard Dynamic Testing

Figure 2. Ejection Seat Mounted to Front of VDT Carriage

4.2 VDT Configuration

A special test fixture was developed which allowed for attachment of the ejection seat to the front face of the VDT carriage. The seat's ejection rail was mounted parallel to the front face of the VDT carriage, which is also parallel to the thrust or impact acceleration vector produced by the VDT facility. This resulted in the seat back tangent plane being forward of the thrust vector approximately 5°, which is appropriate for Mk series ejection seats.

The positive axis of the coordinate system for the test configuration for this program is defined with respect to the orientation of the manikin positioned in the seat mounted to the VDT carriage. The coordinate system is shown for this test configuration in the Figure 3 below.

Figure 3. VDT Facility with Seat and Manikin Showing Impact Coordinate System

4.3 Manikins

All the tests were completed with either a small Case 1 or a large Case 6 anthropometric research manikin used to simulate human response during the testing on the VDT. The test weight of the Case 1 manikin was 128 lb, and the test weight of the Case 6 manikin was 255 lb. The Case 1 and Case 6 manikins were dressed for all tests in a standard USAF flight suit and a pair of USAF boots.

4.4 Specific Test and Related Flight Equipment

The test manikins wore an appropriately sized HGU-55/P flight helmet and MBU-20/P mask in addition to the standard flight suit and boots. The manikins were also fitted with either a PCU-15/P harness (Case 6), or PCU-16/P harness (Case 1). The manikin was centered in the seat and restrained using the ejection seat risers and a standard lap belt configuration.

The 12 FTW at JBSA-Randolph, TX supplied both sets of kneeboard configurations used for this comparative risk assessment. These configurations consisted of the currently authorized kneeboard with paper in-flight guide and checklist weighing approximately 3.0 lbs, and the proposed EFB composed of the iPad Mini and a cover case weighting approximately 1.5 lbs. These weights also included the Velcro straps systems used to restrain each configuration on the leg. The current kneeboard and the proposed EFB configurations are shown in Figure 4 and 5.

Figure 4. Position of Kneeboard on LOIS Manikin's Left Leg Prior to Impact

Figure 5. Position of EFB on LOIS Manikin's Left Leg Prior to Impact

5.0 INSTRUMENTATION AND DATA COLLECTION

Transducers were chosen to provide the optimum resolution over the expected test acceleration and load ranges. Full-scale data ranges were selected to provide the expected full-scale range plus 50% to assure the capture of peak signals. All transducer bridges were balanced for optimum output prior to the start of the program. The appropriate accelerometers were adjusted with software for the effect of gravity by adding the component of a 1 G vector in-line with the force of gravity along the accelerometer axis.

The accelerometer and load transducer coordinate system for the VDT seat fixture in the three orthogonal orientations were shown in Figure 3. The coordinate system is right-hand rule with the z-axis parallel to the spine of the manikin or the seat back, and with positive being up towards the head of the manikin. The x-axis is perpendicular to the z-axis and points outward away from the chest of the manikin or the face of the seat fixture. The y-axis is perpendicular to the x- and z-axes according to the right-hand rule. The manikin coordinate system used was an inverted SAE J211 system (The moments were reverse from the SAE J211 system). Flexion (head rotation forward) was measured as positive, and extension (head rotation rearward) was measured as negative. Compression on the neck load cell and the lumbar load cell was positive, and tension was negative. Flexion of the femur down (relative to the seat pan) was measured negative, and flexion of the femur up away from the seat pan was measured positive.

The linear accelerometers were wired to provide a positive output voltage when the acceleration experienced by the accelerometer was applied in the +x, +y and +z directions. The load cells were wired to provide a positive output voltage when the force exerted by the load cell on the subject was applied in the +x, +y or +z direction. The angular accelerometers were wired to provide a positive output voltage when the angular acceleration experienced by the sensor was applied in the +y direction according to the right-hand rule.

5.1 Facility Instrumentation

Acceleration measurements were taken on the VDT carriage and on the Mk seat by a tri-axial arrangement of linear accelerometers at both locations. The VDT carriage accelerometer package was mounted behind the seat fixture at a point on the carriage the same relative distance up from the bottom of the carriage as the ejection seat pan. The seat accelerometer package was mounted on a rigid support member on the bottom of the seat. The lap belts were also instrumented with in-line load cells on the right and left belt to allow for a pre-load on the belts of 20 lbs ± 5 lbs.

The VDT carriage was instrumented with a tri-axial linear accelerometer package mounted behind the seat structure. An Endevco Model 2262A-200 accelerometer was installed to measure acceleration in the carriage z-axis. Entran Model EGE-72-200 accelerometers were installed to measure acceleration in the carriage y-axis and x-axis. A tri-axial accelerometer package was also mounted on the seat structure close to the seat reference point, and consisted of Entran Model EGV3-F-250 accelerometers for all three axes.

5.2 Manikin Instrumentation

The manikins were instrumented with tri-axial accelerometer packages located in the head, chest, and pelvis, and with 6-axis (3 orthogonal linear forces, 3 orthogonal moments) load cells in the upper neck, lower neck, the lumbar spine/pelvis junction, and the femurs of both the right and left leg. The critical sensor in this effort was the installation of the 6-axis load cells in the legs of the manikins to measure femur bending moments and axial loads in the three orthogonal axes. The critical bending moment for this effort was the bending moment that measured flexion and extension of the femur relative to the pelvis (My) while in a seat position. A load diagram is shown in Figure 6 to illustrate this, and represents the femur from the pelvis is mid-point. The My bending moment is shown at the mid-point of the femur, and would be due to the loading at the distal end of the femur due to the mass of the lower leg and the kneeboard during impact.

The manikin heads were instrumented with a tri-axial linear accelerometer package and a single angular accelerometer measuring rotational acceleration around the head y-axis (flexion/extension motion of the head). The tri-axial accelerometer package was composed of MEAS Model EGCS-S425-250 linear accelerometers. A single Endevco Model 7302B angular accelerometer was mounted next to the tri-axial package to record the head angular acceleration around the y-axis. A tri-axial accelerometer package composed of MEAS Model EGCS-S425-250 linear accelerometers was mounted in the manikin's chest, and a tri-axial accelerometer package composed of Entran Model EGV3-F-250 linear accelerometers was mounted in the manikin's lumbar spine/pelvis junction.

The upper neck of each manikin was instrumented with a 6-axis load cell (Denton Model 1716A) which measured the axial loads in the three orthogonal axes, and the rotational torques around the three orthogonal axes. The Case 6 lower neck was instrumented with a Denton Model 2992 6-axis load cell, and the Case 1 lower neck was instrumented with a Denton Model 5045JTF 6-axis load cell. The lumbar spine of each manikin was instrumented with a Denton Model 1914A 6-axis load cell. The right and left femur of each manikin was also instrumented with a Denton Model 1914A 6-axis load cell.

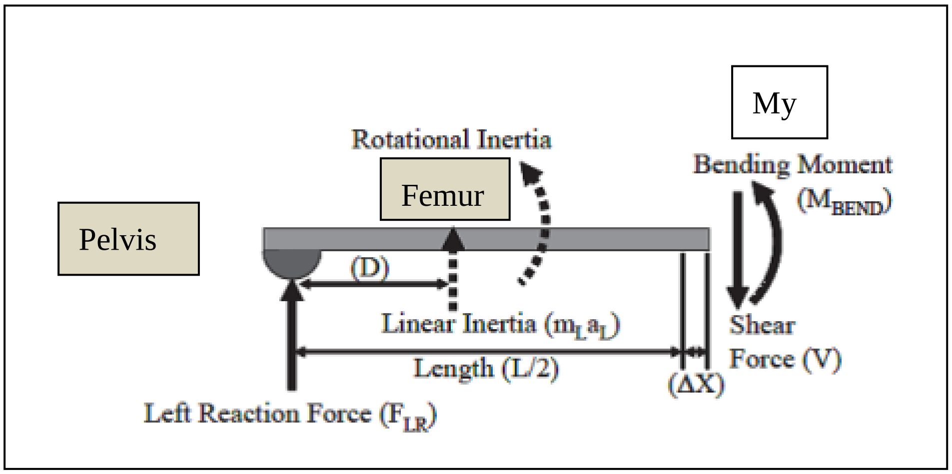

Figure 6. Free-body Diagram to Illustrate Loading and Bending Moment at Mid-Point of Femur (Schematic from Kennedy, VPI Thesis, 2004)

5.3 Transducer Calibration

On-site personnel from Infoscitex, Inc conducted pre- and post-calibrations on all sensors used on the sled, seat fixture, and the manikins with the exception of the neck, lumbar, and femur load cells which are factory calibrated. Calibration records of individual transducers as well as the Standard Practice Instructions are maintained in the biodynamic facility's Impact Information Center. For this test program, a record was made identifying the data channel, transducer manufacturer, model number, serial number, date and sensitivity of pre-calibration, date and sensitivity of post-calibration, and percentage change. Pre and post-calibration information is maintained with the program data. The instrumentation used in this study is listed in the Electronic Instrumentation Data Sheet (See Attachment 1).

5.4 Data Acquisition Control

The Master Instrumentation Control Unit in the Instrumentation Room located between the Horizontal Impulse Accelerator (HIA) and the VDT test facility controlled the data acquisition. A test was initiated when the countdown clock reached zero using a comparator. The comparator was set to start data collection at a pre-selected time based on a positive reading of multiple safety inter-lock sensors used by the facility to protect the facility operators and human test subjects (not used for this program). Data were recorded to establish a zero reference for all transducers prior to restraining the manikin to the divan seat fixture. The reference data were stored separately from the test data and were used in the processing of the test data. A reference mark pulse was generated to mark the electronic data at a pre-selected time after test initiation to place the reference mark close to the impact point. The reference mark time was used as the start time for data processing of the electronic data.

5.5 Data Acquisition System

This research program used the TDAS Pro manufactured by Diversified Technical Systems (DTS), Inc., to collect all the fixture and manikin data for each test as defined by the test matrix. The 64 channel TDAS Pro was mounted on-board the VDT at the top of the impact carriage (Figure 7). The TDAS PRO is a ruggedized, DC powered, fully programmable signal conditioning and recording systems for transducers and events. The TDAS PRO was designed to withstand a 100 G shock. The TDAS unit is covered by plastic on the VDT to protect from water splash due to the water break system employed by the VDT facility.

The signal conditioning accepts a variety of transducers including full and partial bridges, voltage, and piezo-resistive sensors. Transducer signals are amplified, filtered, digitized and recorded in onboard solid-state memory. The data acquisition system is controlled through an Ethernet interface using the Ethernet instruction language. A desktop PC with an Ethernet board configures the TDAS PRO before testing and retrieves the data after each test. For this program, the DAS collected data at a 1K sample rate with a 120 Hz anti-aliasing filter.

Figure 7. Location of TDAS PRO DAS System When Mounted on VDT Carriage

5.6 Quick Look Data Plots

After each test, the filtered data were graphically plotted in a portrait format of 4-6 plots per page, and grouped with similar channels. The spreadsheet of plots also contained pertinent maxima, minima, and respective times of each occurrence. For all data, time = 0 was at initial sled motion. The plots arranged in this fashion included: displacement versus time, force (load) versus time, and acceleration versus time.

5.7 High Speed Video and Photography

Two Phantom Miro-3 High-Speed digital cameras (Figure 8) were used to collect video of each test. The cameras were mounted on-board the VDT carriage at perpendicular and oblique angles relative to the manikin as shown in Figure 9.

The Phantom Micro line is a compact, light-weight, rugged family of cameras targeted at industrial applications ranging from biometric research to automotive crash testing. Rated to survive 100g acceleration this rugged camera can take 512x512 images at up to 2200 frames-per-second (fps). Reduce the resolution to 32 x 32 and achieve frame rates greater than 95,000 fps. With an ISO rating of 4800 (monochrome, saturation-based ISO 12232), the camera has the light sensitivity for the most demanding applications. With shutter speeds as low as 2 microseconds, the user can freeze objects in motion, eliminate blur, and bring out the image detail needed for successful motion analysis. The camera accepts any standard 1" C-mount lens. The Phantom Miro-3 member of the family is optimized for applications such as Hydraulically Controlled, Gas Energized (HYGE) crash simulations used in the automotive industry. Selectable 8-, 10- or 12-bit pixel depth allows the user to choose the dynamic range that best meets the demands of the application. The Miro-3 has a number of external control signals allowing for external triggering, camera synchronization, and time-stamping. The camera has both dynamic RAM and internal flash memory for non-volatile storage. Internal battery power allows the camera to be used in an un-tethered mode and ensures data survivability in case of loss of power.

The images for this study were collected at 500 frames per second (fps). The video files were downloaded and converted to AVI format, and stored in the RH Collaborative Biomechanics Data Bank. Photographs were taken of the test set-up prior to each test. Photographic and video data were stored on an internal network for downloads as requested.

Figure 8. Phantom Miro-3 High-Speed Digital Camera

Figure 9. Phantom Miro-3 Cameras Mounted On-Board VDT Carriage

6.0 EXPERIMENTAL DESIGN

6.1 Crash Event Simulation Testing

The acceleration waveform generated by the VDT was an approximate half-sine wave pulse with a peak acceleration that was dependent on the size of the manikin used for the test. Prior testing of the T-38C catapult indicated that a small occupant would be exposed to a peak acceleration level of approximately 21 G, and a large occupant would be exposed to a peak acceleration of 18 G. The VDT used Plunger # 102 to achieve approximate half-sine wave pulses with these required peak acceleration levels within a 2% tolerance. The test matrix for this test series is shown in Table 1.

Table 1. Test Matrix for Evaluation of Kneeboard Configurations

Test Cell	Peak G	# of Tests	Manikin	Lap Board Configuration
A	18	2	CASE 6	None
B	18	2	CASE 6	Kneeboard
C	18	2	CASE 6	EFB
D	21	2	CASE 1	None
E	21	2	CASE 1	Kneeboard
F	21	2	CASE 1	EFB

6.2 Femur Risk Assessment Methodology

The injury risk assessment was evaluated using the data collected from the instrumented manikins, and were grouped per manikin size to assess the effects of the kneeboard configuration on risk of upper leg injury during the simulated ejection seat catapult. The risk of femur fracture was calculated for both manikins using a probability risk equation developed from the work by Mr. Eric Allen Kennedy for his Master's Thesis at the Virginia Polytechnic Institute and State University (2004). The primary input parameters are the measured moment and the estimated cross-sectional area of the femur for the appropriate sized manikin. The measured moment is the bending moment value (My) recorded by the 6-axis load cell at the mid-point of the femur in the manikin's leg. The cross-sectional area of the femur was estimated for a given percentile occupant by applying an empirical distribution function to the Post Mortem Human Specimen (PMHS) data collected by Kennedy. He developed femur cross-sectional area values for 5th, 50th, and 95th percentile femurs for both male and female individuals. The equation from Kennedy is shown below.

$$\text{Risk of Femur Fracture } (moment, area) = 1 - e^{-e^{[9.3704*\ln(moment)-(46.3140+0.0216*area)]}}$$

7.0 RESULTS

A total of 20 impact tests were completed on the VDT in support of this effort to evaluate the effect of various kneeboard configurations on the risk of femur injury during the catapult phase of ejection. The total number of tests also includes several proof tests to validate the VDT set-up and required impact acceleration level. Analysis of the risk calculations consisted of comparison of calculated femur risk to the currently acceptable USAF risk value for pilot injury.

7.1 Test-by-Test Summary of Crash Event Simulation Testing

The following is a review of the test configuration for each of the impact tests conducted on the VDT with a test-by-test summary documenting test conditions and a brief summary of the key data.

- **Test 6636**: Proof Test; VDT Plunger 102; 21 G peak acceleration input; Case 1 manikin; PCU-16 harness; HGU-55/P helmet size Medium; MBU-20/P, S/N mask; Input Summary: Carriage Z Accel.= 19.59 G; Carriage Velocity = 39.56 ft/s; **UN-SUCCESSFUL PROOF TEST – Input pulse outside approved range requirement.**

- **Test 6637**: Proof Test; VDT Plunger 102; 21 G peak acceleration input; Case 1 manikin; PCU-16 harness; HGU-55/P helmet size Medium; MBU-20/P, S/N mask; Input Summary: Carriage Z Accel.= 20.39 G; Carriage Velocity = 40.73 ft/s; **UN-SUCCESSFUL PROOF TEST – Input pulse outside approved range requirement.**

- **Test 6638**: Proof Test; VDT Plunger 102; 21 G peak acceleration input; Case 1 manikin; PCU-16 harness; HGU-55/P helmet size Medium; MBU-20/P, S/N mask; Input Summary: Carriage Z Accel.= 20.75 G; Carriage Velocity = 41.22 ft/s; **SUCCESSFUL PROOF TEST – Input pulse within approved range requirement.**

- **Test 6639**: Cell D; VDT Plunger 102; 21 G peak acceleration input; Case 1 manikin; PCU-16 harness; HGU-55/P helmet size Medium; MBU-20/P, S/N mask; Input Summary: Carriage Z Accel.= 20.99 G; Carriage Velocity = 41.43 ft/s; **SUCCESSFUL TEST**

- **__Test 6640__**: Cell D; VDT Plunger 102; 21 G peak acceleration input; Case 1 manikin; PCU-16 harness; HGU-55/P helmet size Medium; MBU-20/P, S/N mask; Input Summary: Carriage Z Accel.= 21.09 G; Carriage Velocity = 41.39 ft/s; **SUCCESSFUL TEST**

- **__Test 6641__**: Cell E; VDT Plunger 102; 21 G peak acceleration input; Case 1 manikin; PCU-16 harness; HGU-55/P helmet size Medium; MBU-20/P, S/N mask; Paper Kneeboard configuration; Input Summary: Carriage Z Accel.= 21.12 G; Carriage Velocity = 41.32 ft/s; **SUCCESSFUL TEST – Kneeboard slipped but stayed on upper leg**

- **__Test 6642__**: Cell E; VDT Plunger 102; 21 G peak acceleration input; Case 1 manikin; PCU-16 harness; HGU-55/P helmet size Medium; MBU-20/P, S/N mask; Paper Kneeboard configuration; Input Summary: Carriage Z Accel.= 20.99 G; Carriage Velocity = 41.30 ft/s; **SUCCESSFUL TEST – Kneeboard slipped but stayed on upper leg**

- **__Test 6643__**: Cell F; VDT Plunger 102; 21 G peak acceleration input; Case 1 manikin; PCU-16 harness; HGU-55/P helmet size Medium; MBU-20/P, S/N mask; EFB configuration; Input Summary: Carriage Z Accel.= 21.18 G; Carriage Velocity = 41.36 ft/s; **SUCCESSFUL TEST – EFB stayed on upper leg, but barely restrained by side clamps**

- **__Test 6644__**: Cell F; VDT Plunger 102; 21 G peak acceleration input; Case 1 manikin; PCU-16 harness; HGU-55/P helmet size Medium; MBU-20/P, S/N mask; EFB configuration; Input Summary: Carriage Z Accel.= 20.88 G; Carriage Velocity = 41.33 ft/s; **SUCCESSFUL TEST – EFB slipped off upper leg, but still restrained on lower leg over shin**

- **__Test 6645__**: Cell F; VDT Plunger 102; 21 G peak acceleration input; Case 1 manikin; PCU-16 harness; HGU-55/P helmet size Medium; MBU-20/P, S/N mask; EFB configuration; Input Summary: Carriage Z Accel.= 20.95 G; Carriage Velocity = 41.38 ft/s; **SUCCESSFUL TEST – Additional test to evaluate if femur loading affected by slippage (EFB restrained on upper leg with Buckle Clip Strap and additional tape); No movement of EFB**

- **__Test 6646__**: Cell E; VDT Plunger 102; 21 G peak acceleration input; Case 1 manikin; PCU-16 harness; HGU-55/P helmet size Medium; MBU-20/P, S/N mask; Paper Kneeboard configuration; Input Summary: Carriage Z Accel.= 21.02 G; Carriage Velocity = 41.38 ft/s; **SUCCESSFUL TEST – Additional test to evaluate if hand placement affected kneeboard slippage and femur loading; no kneeboard slippage**

- **__Test 6647__**: Proof Test; VDT Plunger 102; 18 G peak acceleration input; Case 6 manikin; PCU-15 harness; HGU-55/P helmet size X-Large; MBU-20/P, M/W mask; Input Summary: Carriage Z Accel.= 16.20 G; Carriage Velocity = 36.44 ft/s; **UN-SUCCESSFUL PROOF TEST – Input pulse outside approved range requirement.**

- **<u>Test 6648</u>**: Cell A; VDT Plunger 102; 18 G peak acceleration input; Case 6 manikin; PCU-15 harness; HGU-55/P helmet size X-Large; MBU-20/P, M/W mask; Input Summary: Carriage Z Accel.= 18.24 G; Carriage Velocity = 38.89 ft/s; **SUCCESSFUL TEST**

- **<u>Test 6649</u>**: Cell A; VDT Plunger 102; 18 G peak acceleration input; Case 6 manikin; PCU-15 harness; HGU-55/P helmet size X-Large; MBU-20/P, M/W mask; Input Summary: Carriage Z Accel.= 18.14 G; Carriage Velocity = 38.59 ft/s; **SUCCESSFUL TEST**

- **<u>Test 6650</u>**: Cell B; VDT Plunger 102; 18 G peak acceleration input; Case 6 manikin; PCU-15 harness; HGU-55/P helmet size X-Large; MBU-20/P, M/W mask; Paper Kneeboard Configuration; Input Summary: Carriage Z Accel.= 18.37 G; Carriage Velocity = 38.64 ft/s; **SUCCESSFUL TEST – Kneeboard slipped off upper leg, but remained attached to lower leg with Velcro**

- **<u>Test 6651</u>**: Cell B; VDT Plunger 102; 18 G peak acceleration input; Case 6 manikin; PCU-15 harness; HGU-55/P helmet size X-Large; MBU-20/P, M/W mask; Paper Kneeboard Configuration; Input Summary: Carriage Z Accel.= 17.83 G; Carriage Velocity = 38.31 ft/s; **SUCCESSFUL TEST – Kneeboard slipped off upper leg, but remained attached to lower leg with Velcro**

- **<u>Test 6652</u>**: Cell B; VDT Plunger 102; 18 G peak acceleration input; Case 6 manikin; PCU-15 harness; HGU-55/P helmet size X-Large; MBU-20/P, M/W mask; Paper Kneeboard Configuration; Input Summary: Carriage Z Accel.= 17.83 G; Carriage Velocity = 38.31 ft/s; **SUCCESSFUL TEST – Additional test to evaluate if femur loading affected by slippage (Kneeboard restrained on upper leg with Velcro strap and additional tape); No movement of Kneeboard during impact**

- **<u>Test 6653</u>**: Cell C; VDT Plunger 102; 18 G peak acceleration input; Case 6 manikin; PCU-15 harness; HGU-55/P helmet size X-Large; MBU-20/P, M/W mask; EFB Configuration; Input Summary: Carriage Z Accel.= 17.91 G; Carriage Velocity = 38.45 ft/s; **SUCCESSFUL TEST – EFB slipped off upper leg, but remained attached to lower leg with Buckle Clip Strap; EFB remained attached in side clamps**

- **<u>Test 6654</u>**: Cell C; VDT Plunger 102; 18 G peak acceleration input; Case 6 manikin; PCU-15 harness; HGU-55/P helmet size X-Large; MBU-20/P, M/W mask; EFB Configuration; Input Summary: Carriage Z Accel.= 17.93 G; Carriage Velocity = 38.43 ft/s; **SUCCESSFUL TEST – EFB slipped off upper leg, but Buckle Clip Strap remained attached to upper leg; EFB slipped out of the side clamps**

- **<u>Test 6655</u>**: Cell C; VDT Plunger 102; 18 G peak acceleration input; Case 6 manikin; PCU-15 harness; HGU-55/P helmet size X-Large; MBU-20/P, M/W mask; EFB Configuration; Input Summary: Carriage Z Accel.= 17.98 G; Carriage Velocity = 38.41 ft/s; **SUCCESSFUL TEST – Additional test to evaluate if femur loading affected by slippage of Buckle Clip**

Strap or failure of EFB side clamps (EFB restrained on upper leg with Buckle Clip Strap strap and additional tape); No movement of EFB during impact

7.2 Femur Risk Assessment Results

All tests were conducted according to the test matrix shown in Table 1. The Case 6 manikin required the 18 G peak accelerations, and the Case 1 manikin required the 21 G peak accelerations. The VDT acceleration input for the 18 G tests (non-proof) was 18.06 ± 0.18 G, and the velocity change was 38.52 ± 0.18 ft/s. The acceleration input for the 21 G tests (non-proof) was 21.02 ± 0.10 G, and the velocity change was 41.36 ± 0.04 ft/s. These peak acceleration level and velocity change summaries indicate that the VDT impact environment was well controlled during the duration of the program.

Data collected from the femur load cells were grouped per manikin size to assess effects of kneeboard configuration on risk of upper leg injury during the simulated ejection seat catapult. The risk of femur fracture was calculated for both manikins using the probability risk equation shown previously. The risk value was calculated using the measured My femur moment, and the estimated cross-sectional area of the femur for the appropriate sized manikin. The data for the Case 1 small manikin (5^{th} percentile female) is shown in Table 2. The data for the Case 6 large manikin (95^{th} percentile male) is shown below in Table 3.

Table 2. Summary of Small Manikin Femur Torque as a Function of Kneeboard Configuration

Test Cell	Kneeboard Configuration	Impact Acceleration (G)	Left Femur My Torque (in-lb)	Risk of Femur Fracture (% Probability)
D	None	21	1279 ± 76	0.5
E	Paper	21	1603 ± 193	4.7
F	EFB	21	1549 ± 82	3.5

Table 3. Summary of Large Manikin Femur Torque as a Function of Kneeboard Configuration

Test Cell	Kneeboard Configuration	Impact Acceleration (G)	Left Femur My Torque (in-lb)	Risk of Femur Fracture (% Probability)
A	None	18	3260 ± 497	1.3
B	Paper	18	3553 ± 106	2.8
C	EFB	18	3375 ± 203	2.0

The data from Table 2 for the Case 1 small manikin indicates what was expected in terms of measured femur torque and calculated risk of injury. Both kneeboard configurations generated higher loading and probability of injury values than the leg only, and the heavier paper kneeboard configuration generated slightly higher loading and probability of injury value. Statistical significance was not calculated due to the limited number of tests.

The data from Table 3 for the Case 6 large manikin also indicates what was expected in terms of measured femur torque and calculated risk of injury. Both kneeboard configurations generated higher loading and probability of injury values than the leg only, and the heavier paper kneeboard configuration generated slightly higher loading and probability of injury value. Statistical significance was not calculated due to the limited number of tests.

7.3 Observational Data Results

Evaluation of the test set-up after each impact provided some important information relative to the method used to restrain the kneeboard configurations to the leg. The tests with the large manikin showed that the Velcro strap and the Buckle Clip Strap had a difficult time keeping the kneeboard configurations on the upper leg during the impact. This was true for both the paper kneeboard configuration and the proposed EFB configuration. The Velcro strap used for the paper kneeboard allowed the kneeboard to slip off the upper leg over the knee and down to the lower leg for the first two tests in this configuration (Figure 10). The Velcro did not fail and the paper guide and checklist never separated from the leg. An additional test was run with additional tape used to secure the kneeboard to the leg and prevent the configuration from slipping to see if this had an effect on the measured load. The kneeboard stayed on the upper leg, and the measured torque with this additional restraint was still within the range of the first two tests.

Figure 10. Post-Test Position of Paper Kneeboard Configuration for Test 6650

The tests with the large manikin and the EFB configuration had similar issues with the Buckle Clip Strap, however, the EFB unit slip over the knee on one test, and the EFB unit separated from the side clamps on the second test and was restrained by secondary parachute cord (Figures 11 and 12).   An additional test was run with additional tape, used to secure the EFB to the leg and prevent the unit from slipping off the leg and out of the side clamps, to see if this had an effect on the measured load. The EFB stayed on the upper leg, and the measured torque with this additional restraint was still within the range of the first two tests.

Figure 11. Post-Test Position of EFB Configuration for Test 6653with Case 6 Manikin

Figure 12. Post-Test Position of EFB Configuration for Test 6654 with Case 6 Manikin

The tests with the small manikin showed similar results with the large manikin in terms of the Velcro straps keeping the kneeboard configurations on the upper leg during the impact. This was true for both the paper kneeboard configuration and the proposed EFB configuration. The Velcro strap used for the paper kneeboard allowed the kneeboard to slip on the upper leg; however, un-like with the large manikin, the paper kneeboard did not slide down to the lower leg. The Velcro did not fail and the paper guide and checklist never separated from the leg.

The Buckle Clip Strap for the EFB configuration also did not allow the EFB to slip on one test, but on the second test, the EFB configuration slipped off the upper leg down to the lower leg. The EFB did not separate from the side clamps on any test. An additional test was run with additional tape used to secure the EFB to the leg and prevent the configuration from slipping to see if this had an effect on the measured load. The EFB stayed on the upper leg, and the measured torque with this additional restraint was still within the range of the first two tests.

8.0 SUMMARY AND CONCLUSIONS

The 12th Flying Training Wing (12 FTW) at JBSA Randolph, TX is currently investigating the risk of using Electronic Flight Bags (EFB) in ejection capable aircraft, and in particular, the T-38C and the T-6. EFB's have been in use in commercial aviation and other Air Force commands for years, and there is an increasing effort to provide this equipment for all pilots in all USAF training aircraft. Currently, the only operational USAF ejection aircraft flying with EFBs attached to their legs are the 394th CTS T-38As at Whiteman AFB. Since there is no current research, or laboratory test data to support a risk analysis, this unit is operating under command assumed risk

The Aircrew Biodynamics and Protection (ABP) Team of AFRL (711 HPW/RHCPT) conducted a short series of tests to support an objective analysis of determining injury risk to a pilot ejecting from a T-38C with current or proposed kneeboard technology. This effort was initiated to provide data to assist with ejection injury analysis in order to assess if there is additional risk associated with the proposed EFB configuration consisting of an Apple iPad Mini with a shock case.

A Vertical Drop Tower (VDT) facility was setup with a Mk series ejection seat mounted in a +z-axis impact orientation on the front vertical surface of the tower's drop carriage. The seat's ejection rail was mounted parallel to the thrust or impact acceleration vector produced by the VDT facility. This resulted in the seat back tangent plane being forward of the thrust vector approximately 5°, which is appropriate for Mk series ejection seats. The acceleration waveform generated by the VDT was an approximate half-sin pulse with a peak acceleration that was dependent on the size of the manikin used for the test. Prior testing of the T-38C catapult indicated that a small occupant would be exposed to a peak acceleration level of approximately 21 G, and a large occupant would be exposed to a peak acceleration of 18 G. The 12 FTW at JBSA-Randolph, TX supplied both sets of kneeboard equipment used for this comparative evaluation. These consisted of the currently authorized kneeboard with paper in-flight guide and checklist weighing approximately 3.0 lbs, and the proposed EFB composed of the iPad Mini and a cover case weighting approximately 1.5 lbs. These weights also included the Velcro strap Buckle Clip Strap used to restrain each configuration on the leg.

The laboratory tests were designed to evaluate the effect of the kneeboard configuration on the risk of femur fracture during the catapult phase of ejection. A comparison was made between a non-kneeboard configuration, the current paper kneeboard configuration, and the proposed EFB configuration. The USAF currently accepts up to a 5% risk of injury to the spine during the catapult phase of ejection; therefore, this injury risk was also used for the kneeboard configuration comparisons. Data from the test series indicated the risk of using either kneeboard configuration (paper or EFB) was below 5% regardless of the size of the occupant. In general, the data indicated that larger occupants were at a lower risk than the small occupants with the larger occupants having a risk of femur fracture in the 2 to 3% range, and the small occupants having a risk of femur fracture in the 3.5 to 4.5% range. This was most likely due to the small occupants having a smaller relative femur cross-sectional area, and also being exposed to a greater catapult acceleration based on the current seat installed in the aircraft.

The observational data indicated that the current Velcro strap and the Buckle Clip Strap may not sufficiently support either kneeboard configuration regardless of the size of the occupant; however, the larger occupant had issues with both the paper and EFB configuration in the this test series. The configurations tended to slip off the upper leg and move over the knee to end up resting on the lower leg. The EFB released from its clamps on only one test with the large occupant. The slippage may have been due to the laboratory test set-up since the seat configuration had the leg slightly decline away from the torso.

Recommendations are to investigate a Velcro or Buckle Clip strap configuration that possibly interfaces through loops in the flight suit garment, and to investigate a better side clamp system for the EFB. The laboratory tests indicated that the side clamps may not sufficiently hold the EFB during the catapult.

In addition, there is a potential risk of injury to the ejecting aircrew if either the paper kneeboard or the EFB become dislodged during windblast following the catapult stroke, and then this equipment strikes the head/neck of the ejecting occupant. It is recommended to investigate the adequacy of the Velcro restraint for the paper kneeboard configuration, and the Buckle Clip Strap and side clamp restraint for the EFB configuration, to hold the items to the leg during windblast if this has not already been evaluated.

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ATTACHMENT 1: ELECTRONIC DATA CHANNELS

<table>
<tr><td colspan="6">PROGRAM: Vertical and Horizontal Impact Tests of the Joint Aircrew Mask (JSAM); Kneeboard Assessment</td><td colspan="7">TEST DATES: 6 - 7 April 2015: 14 April 2015</td></tr>
<tr><td colspan="6">STUDY NUMBER: 201504</td><td colspan="7">TEST NUMBERS: 6636 - 6655; 6656 - 6664</td></tr>
<tr><td colspan="6">FACILITY: VDT</td><td colspan="7">SAMPLE RATE: 1KHz</td></tr>
<tr><td colspan="6">DATA COLLECTION SYSTEM: TDAS PRO;
Off Board TDAS Single 8 Channel module</td><td colspan="7">FILTER FREQUENCY: 120 Hz</td></tr>
<tr><td colspan="6"></td><td colspan="7">TRANSDUCER RANGE (VOLTS): +/- 5V</td></tr>
<tr><td rowspan="2">DATA CHANNEL</td><td rowspan="2">DATA POINT</td><td rowspan="2">TRANSDUCER MFG. & MODEL</td><td rowspan="2">SERIAL NUMBER</td><td colspan="2">PRE-CAL</td><td colspan="2">POST-CAL</td><td rowspan="2">% D</td><td rowspan="2">DAS SENSITIVITY</td><td rowspan="2">BRIDGE</td><td rowspan="2">FULL SCALE</td><td rowspan="2">NOTES</td></tr>
<tr><td>DATE</td><td>SENS</td><td>DATE</td><td>SENS</td></tr>
<tr><td>1</td><td>CARRIAGE X ACCEL (G)</td><td>ENTRAN EGE-72-200</td><td>93C93 C19-R02</td><td>26-Mar-15</td><td>2.2316 mv/g at 10V exc</td><td>17-Jun-15</td><td>2.2191 mv/g at 10V exc</td><td>-0.6</td><td>.22316 mvv/g</td><td>FULL</td><td>50 G</td><td>Used on all tests</td></tr>
<tr><td>2</td><td>CARRIAGE Y ACCEL (G)</td><td>ENTRAN EGE-72-200</td><td>93C93 C19-R07</td><td>26-Mar-15</td><td>2.4066 mv/g at 10V exc</td><td>17-Jun-15</td><td>2.3984 mv/g at 10V exc</td><td>-0.3</td><td>.24066 mv/v/g</td><td>FULL</td><td>25 G</td><td>Used on all tests</td></tr>
<tr><td>3</td><td>CARRIAGE Z ACCEL (G)</td><td>ENDEVCO 2262A-200</td><td>HM75</td><td>26-Mar-15</td><td>4.3913 mv/g at 10V exc</td><td>17-Jun-15</td><td>4.4032 mv/g at 10V exc</td><td>0.3</td><td>.43913 mv/v/g</td><td>FULL</td><td>25 G</td><td>Used on all tests</td></tr>
<tr><td>5</td><td>SEAT PAN X ACCEL (G)</td><td>ENTRAN EGV3-F-250</td><td>M090CH (X)</td><td>15-Feb-15</td><td>.7785 mv/g at 10V exc</td><td>18-Jun-15</td><td>.7814 mv/g at 10V exc</td><td>0.4</td><td>.07785 mv/v/g</td><td>FULL</td><td>250 G</td><td>Used on all tests</td></tr>
<tr><td>6</td><td>SEAT PAN Y ACCEL (G)</td><td>ENTRAN EGV3-F-250</td><td>M090CH (Y)</td><td>15-Feb-15</td><td>.8020 mv/g at 10V exc</td><td>18-Jun-15</td><td>.8037 mv/g at 10V exc</td><td>0.2</td><td>.08020 mv/v/g</td><td>FULL</td><td>250 G</td><td>Used on all tests</td></tr>
<tr><td>7</td><td>SEAT PAN Z ACCEL (G)</td><td>ENTRAN EGV3-F-250</td><td>M090CH (Z)</td><td>15-Feb-15</td><td>.6804 mv/g at 10V exc</td><td>18-Jun-15</td><td>.6801 mv/g</td><td>-0.1</td><td>.06804 mv/v/g</td><td>FULL</td><td>250 G</td><td>Used on all tests</td></tr>
</table>

							at 10V exc					
8	INT HEAD X ACCEL (G)	MEAS SPEC EGCS-S425-250	R1307X	09-Oct-14	.5797 mv/g at 10V exc	04-May-15	.5758 mv/g at 10V exc	-0.7	.05797 mv/v/g	FULL	100 G	CASE 1 tests 6636-6646; 6656-6660
8	INT HEAD X ACCEL (G)	MEAS SPEC EGCS-S425-250	R13080	26-Mar-15	.5806 mv/g at 10V exc	12-May-15	.5795 mv/g at 10V exc	-0.2	.05806 mv/v/g	FULL	100 G	CASE 6 tests 6647-6655; 6661-6664
9	INT HEAD Y ACCEL (G)	MEAS SPEC EGCS-S425-250	R1307Y	09-Oct-14	.5563 mv/g at 10V exc	04-May-15	.5520 mv/g at 10V exc	-0.8	.05563 mv/v/g	FULL	100 G	CASE 1 tests 6636-6646; 6656-6660
9	INT HEAD Y ACCEL (G)	MEAS SPEC EGCS-S425-250	R130NR	26-Mar-15	.5877 mv/g at 10V exc	12-May-15	.5885 mv/g at 10V exc	0.1	.05877 mv/v/g	FULL	100 G	CASE 6 tests 6647-6655; 6661-6664
10	INT HEAD Z ACCEL (G)	MEAS SPEC EGCS-S425-250	13083	09-Oct-14	.5899 mv/g at 10V exc	04-May-15	.5868 mv/g at 10V exc	-0.5	.05899 mv/v/g	FULL	100 G	CASE 1 tests 6636-6646; 6656-6660
10	INT HEAD Z ACCEL (G)	MEAS SPEC EGCS-S425-250	T13130	02-Dec-14	.6352 mv/g at 10V exc	12-May-15	.6275 mv/g at 10V exc	-1.2	.06352 mv/v/g	FULL	100 G	CASE 6 tests 6647-6655; 6661-6664
11	INT HEAD Ry ANG ACCEL (RAD/SEC2)	ENDEVCO 7302B	10229	19-Aug-14	3.53 uv/rad/sec2 at 10V exc	05-May-15	3.62 uv/rad/sec2 at 10V exc	2.5	.000353 mv/v/rad/sec2	FULL	5000 RAD/SEC2	CASE 1 tests 6636-6646; 6656-6660
11	INT HEAD Ry ANG ACCEL (RAD/SEC2)	ENDEVCO 7302B	10173	25-Oct-14	3.25 uv/rad/sec2 at 10V exc	13-May-15	3.29 uv/rad/sec2 at 10V exc	1.2	.000325 mv/v/rad/sec2	FULL	5000 RAD/SEC2	CASE 6 tests 6647-6655; 6661-6664
12	INT UPPER NECK X FORCE (LB)	DENTON 1716A	625	14-Oct-14	8.19 uv/lb at 10V exc	05-May-15	8.17 uv/lb at 10V exc	-0.2	.000819 mv/v/lb	FULL	2000 LB	CASE 1 tests 6636-6646; 6656-6660
12	INT UPPER NECK X FORCE (LB)	DENTON 1716A	718	16-Dec-14	8.13 uv/lb at 10V exc	19-May-15	8.12 uv/lb at 10V exc	-0.1	.000813 mv/v/lb	FULL	2000 LB	CASE 6 tests 6647-6655; 6661-6664

13	INT UPPER NECK Y FORCE (LB)	DENTON 1716A	625	14-Oct-14	8.55 uv/lb at 10V exc	05-May-15	8.50 uv/lb at 10V exc	-0.6	.000855 mv/v/lb	FULL	2000 LB	CASE 1 tests 6636-6646; 6656-6660
13	INT UPPER NECK Y FORCE (LB)	DENTON 1716A	718	16-Dec-14	8.38 uv/lb at 10V exc	19-May-15	8.28 uv/lb at 10V exc	-1.2	.000838 mv/v/lb	FULL	2000 LB	CASE 6 tests 6647-6655; 6661-6664
14	INT UPPER NECK Z FORCE (LB)	DENTON 1716A	625	14-Oct-14	4.00 uv/lb at 10V exc	05-May-15	3.98 uv/lb at 10V exc	-0.5	.000400 mv/v/lb	FULL	3000 LB	CASE 1 tests 6636-6646; 6656-6660
14	INT UPPER NECK Z FORCE (LB)	DENTON 1716A	718	16-Dec-14	4.43 uv/lb at 10V exc	19-May-15	4.43 uv/lb at 10V exc	0	.000443 mv/v/lb	FULL	3000 LB	CASE 6 tests 6647-6655; 6661-6664
15	INT UPPER NECK Mx TORQUE (IN-LB)	DENTON 1716A	625	14-Oct-14	6.75 uv/in-lb at 10V exc	05-May-15	6.65 uv/in-lb at 10V exc	-1.5	.000675 mv/v/in-lb	FULL	2500 IN-LB	CASE 1 tests 6636-6646; 6656-6660
15	INT UPPER NECK Mx TORQUE (IN-LB)	DENTON 1716A	718	16-Dec-14	6.62 uv/in-lb at 10V exc	19-May-15	6.56 uv/in-lb at 10V exc	-0.9	.000662 mv/v/in-lb	FULL	2500 IN-LB	CASE 6 tests 6647-6655; 6661-6664
16	INT UPPER NECK My TORQUE (IN-LB)	DENTON 1716A	625	14-Oct-14	6.83 uv/in-lb at 10V exc	05-May-15	6.73 uv/in-lb at 10V exc	-1.5	.000683 mv/v/in-lb	FULL	2500 IN-LB	CASE 1 tests 6636-6646; 6656-6660
16	INT UPPER NECK My TORQUE (IN-LB)	DENTON 1716A	718	16-Dec-14	6.68 uv/in/lb at 10V exc	19-May-15	6.61 uv/lb at 10V exc	-1.1	.000668 mv/v/in-lb	FULL	2500 IN-LB	CASE 6 tests 6647-6655; 6661-6664
17	INT UPPER NECK Mz TORQUE (IN-LB)	DENTON 1716A	625	14-Oct-14	9.22 uv/in-lb at 10V exc	05-May-15	9.03 uv/in-lb at 10V exc	-2.1	.000922 mv/v/in-lb	FULL	2500 IN-LB	CASE 1 tests 6636-6646; 6656-6660
17	INT UPPER NECK Mz TORQUE (IN-LB)	DENTON 1716A	718	16-Dec-14	9.00 uv/in-lb at 10V exc	19-May-15	8.84 uv/in-lb at 10V exc	-1.8	.000900 mv/v/in-lb	FULL	2500 IN-LB	CASE 6 tests 6647-6655; 6661-6664
18	INT LOWER NECK X FORCE (LB)	DENTON 5045JTF	89	10-Mar-15	7.79 uv/lb at 10V exc	NA	NA	NA	.000779 mv/v/lb	FULL	3000 LB	CASE 1 tests 6636-6646; 6656-6660

18	INT LOWER NECK X FORCE (LB)	DENTON 2992	139	10-Mar-15	18.53 uv/lb at 10V exc	NA	NA	NA	.001853 mv/v/lb	FULL	1500 LB	CASE 6 tests 6647-6655; 6661-6664. Customer did not want post cals.
19	INT LOWER NECK Y FORCE (LB)	DENTON 5045JTF	89	10-Mar-15	7.87 uv/lb at 10V exc	NA	NA	NA	.000787 mv/v/lb	FULL	3000LB	CASE 1 tests 6636-6646; 6656-6660. Customer did not want post cals.
19	INT LOWER NECK Z FORCE (LB)	DENTON 2992	139	10-Mar-15	18.57 uv/lb at 10V exc	NA	NA	NA	.001857 mv/v/lb	FULL	1500 LB	CASE 6 tests 6647-6655; 6661-6664. Customer did not want post cals.
20	INT LOWER NECK Z FORCE (LB)	DENTON 5045JTF	89	10-Mar-15	4.46 uv/lb at 10V exc	NA	NA	NA	.000446 mv/v/lb	FULL	3000 LB	CASE 1 tests 6636-6646; 6656-6660. Customer did not want post cals.
20	INT LOWER NECK X FORCE (LB)	DENTON 2992	139	10-Mar-15	7.75 uv/lb at 10V exc	NA	NA	NA	.000775 mv/v/lb	FULL	2000 LB	CASE 6 tests 6647-6655; 6661-6664. Customer did not want post cals.
21	INT LOWER NECK Mx TORQUE (IN-LB)	DENTON 5045JTF	89	10-Mar-15	4.81 uv/in-lb at 10V exc	NA	NA	NA	.000481 mv/v/in-lb	FULL	4000 IN-LB	CASE 1 tests 6636-6646; 6656-6660. Customer did not want post cals.
21	INT LOWER NECK Mx TORQUE (IN-LB)	DENTON 2992	139	10-Mar-15	4.92 uv/in-lb at 10V exc	NA	NA	NA	.000492 mv/v/in-lb	FULL	3000 IN-LB	CASE 6 tests 6647-6655; 6661-6664. Customer did not want post cals.
22	INT LOWER NECK My TORQUE (IN-LB)	DENTON 5045JTF	89	10-Mar-15	4.97 uv/in-lb at 10V exc	NA	NA	NA	.000497 mv/v/in-lb	FULL	4000 IN-LB	CASE 1 tests 6636-6646; 6656-6660. Customer did not want post cals.
22	INT LOWER NECK My TORQUE (IN-LB)	DENTON 2992	139	10-Mar-15	5.05 uv/in-lb at 10V exc	NA	NA	NA	.000505 mv/v/in-lb	FULL	3000 IN-LB	CASE 6 tests 6647-6655; 6661-6664. Customer did not want post cals.
23	INT LOWER NECK Mz TORQUE (IN-LB)	DENTON 5045JTF	89	10-Mar-15	6.59 uv/in-lb at 10V exc	NA	NA	NA	.000659 mv/v/in-lb	FULL	3000 IN-LB	CASE 1 tests 6636-6646; 6656-6660. Customer did not want post cals.

23	INT LOWER NECK Mz TORQUE (IN-LB)	DENTON 2992	139	10-Mar-15	8.98 uv/in-lb at 10V exc	NA	NA	NA	.000898 mv/v/in-lb	FULL	2000 IN-LB	CASE 6 tests 6647-6655; 6661-6664. Customer did not want post cals.
24	INT CHEST X ACCEL (G)	MEAS SPEC EGCS-S425-250	R130NQ	15-Aug-14	.5800 mv/g at 10V exc	04-May-15	.5738 mv/g at 10V exc	-1.1	.05800 mv/v/g	FULL	100 G	CASE 1 tests 6636-6646; 6656-6660
24	INT CHEST X ACCEL (G)	MEAS SPEC EGCS-S425-250	R13081	09-Oct-14	.6009 mv/g at 10V exc	12-May-15	.5956 mv/g at 10V exc	-0.9	.06009 mv/v/g	FULL	100 G	CASE 6 tests 6647-6655; 6661-6664
25	INT CHEST Y ACCEL (G)	MEAS SPEC EGCS-S425-250	R130P1	09-Oct-15	.6448 mv/g at 10V exc	04-May-15	.6360 mv/g at 10V exc	-1.4	.06448 mv/v/g	FULL	100 G	CASE 1 tests 6636-6646; 6656-6660
25	INT CHEST Y ACCEL (G)	MEAS SPEC EGCS-S425-250	R13084	09-Oct-14	.5698 mv/g at 10V exc	12-May-15	.5650 mv/g at 10V exc	-0.8	.05698 mv/v/g	FULL	100 G	CASE 6 tests 6647-6655; 6661-6664
26	INT CHEST Z ACCEL (G)	MEAS SPEC EGCS-S425-250	R1103Y	15-Aug-14	.5546 mv/g at 10V exc	04-May-15	.5500 mv/g at 10V exc	-0.8	.05546 mv/v/g	FULL	100 G	CASE 1 tests 6636-6646; 6656-6660
26	INT CHEST Z ACCEL (G)	MEAS SPEC EGCS-S425-250	R13082	09-Oct-14	.5766 mv/g at 10V exc	12-May-15	.5724 mv/g at 10V exc	-0.7	.05766 mv/v/g	FULL	100 G	CASE 6 tests 6647-6655; 6661-6664
27	INT CHEST Ry ANG ACCEL (RAD/SEC2)	ENDEVCO 7302B	10203	19-Aug-14	4.42 uv/rad/sec2 at 10V exc	05-May-15	4.28 uv/rad/sec2 at 10V exc	-3	.000442 mv/v/rad/sec2	FULL	5000 RAD/SEC2	CASE 1 tests 6636-6646; 6656-6660
27	INT CHEST Ry ANG ACCEL (RAD/SEC2)	ENDEVCO 7302B	10184	19-Aug-14	3.38 uv/rad/sec2 at 10V exc	13-May-15	3.35 uv/rad/sec2 at 10V exc	-0.9	.000338 mv/v/rad/sec2	FULL	5000 RAD/SEC2	CASE 6 tests 6647-6655; 6661-6664
28	INT LUMBAR X ACCEL (G)	ENTRAN EGV3-F-250	Y1117N (X)	09-Feb-15	.7986 mv/g at 10V exc	04-May-15	.7998 mv/g at 10V exc	0.2	.07986 mv/v/g	FULL	100 G	CASE 1 tests 6636-6646; 6656-6660

28	INT LUMBAR X ACCEL (G)	ENTRAN EGV3-F-250	M110LO (X)	18-Feb-15	.8082 mv/g at 10V exc	12-May-15	.8102 mv/g at 10V exc	0.3	.08082 mv/v/g	FULL	100 G	CASE 6 tests 6647-6655; 6661-6664
29	INT LUMBAR Y ACCEL (G)	ENTRAN EGV3-F-250	Y1117N (Y)	09-Feb-15	.8116 mv/g at 10V exc	04-May-15	.8128 mv/g at 10V exc	0.1	.08116 mv/v/g	FULL	100 G	CASE 1 tests 6636-6646; 6656-6660
29	INT LUMBAR Y ACCEL (G)	ENTRAN EGV3-F-250	M110LO (Y)	18-Feb-15	.8012 mv/g at 10V exc	12-May-15	.8015 mv/g at 10V exc	0.1	.08012 mv/v/g	FULL	100 G	CASE 6 tests 6647-6655; 6661-6664
30	INT LUMBAR Z ACCEL (G)	ENTRAN EGV3-F-250	Y1117N (Z)	09-Feb-15	.7661 mv/g at 10V exc	04-May-15	.7695 mv/g at 10V exc	0.4	.07661 mv/v/g	FULL	100 G	CASE 1 tests 6636-6646; 6656-6660
30	INT LUMBAR Z ACCEL (G)	ENTRAN EGV3-F-250	M110LO (Z)	18-Feb-15	.7319 mv/g at 10V exc	12-May-15	7325 mv/g at 10V exc	0.1	.07319 mv/v/g	FULL	100 G	CASE 6 tests 6647-6655; 6661-6664
31	INT LUMBAR X FORCE (LB)	DENTON 1914A	310	14-Oct-14	6.71 uv/lb at 10V exc	06-May-15	6.68 uv/lb at 10V exc	-0.4	.000671 mv/v/lb	FULL	3000 LB	CASE 1 tests 6636-6646; 6656-6660
31	INT LUMBAR X FORCE (LB)	DENTON 1914A	365	13-Mar-15	6.52 uv/lb at 10V exc	19-May-15	6.53 uv/lb at 10V exc	0.2	.000652 mv/v/lb	FULL	3000 LB	CASE 6 tests 6647-6655; 6661-6664
32	INT LUMBAR Y FORCE (LB)	DENTON 1914A	310	14-Oct-14	6.72 uv/lb at 10V exc	06-May-15	6.61 uv/lb at 10V exc	-1.6	.000672 mv/v/lb	FULL	3000 LB	CASE 1 tests 6636-6646; 6656-6660
32	INT LUMBAR Y FORCE (LB)	DENTON 1914A	365	13-Mar-15	6.49 uv/lb at 10V exc	19-May-15	6.42 uv/lb at 10V exc	-1.1	.000649 mv/v/lb	FULL	3000 LB	CASE 6 tests 6647-6655; 6661-6664
33	INT LUMBAR Z FORCE (LB)	DENTON 1914A	310	14-Oct-14	2.81 uv/lb at 10V exc	06-May-15	2.77 uv/lb aty 10V exc	-1.4	.000281 mv/v/lb	FULL	5000 LB	CASE 1 tests 6636-6646; 6656-6660
33	INT LUMBAR Z FORCE (LB)	DENTON 1914A	365	13-Mar-15	2.67 uv/lb at 10V exc	19-May-15	2.68 uv/lb at 10V exc	0.4	.000267 mv/v/lb	FULL	5000 LB	CASE 6 tests 6647-6655; 6661-6664
34	INT LUMBAR Mx TORQUE (IN-LB)	DENTON 1914A	310	14-Oct-14	5.23 uv/in-lb at 10V exc	06-May-15	5.21 uv/in-lb	-0.4	.000523 mv/v/in-lb	FULL	3000 IN-LB	CASE 1 tests 6636-6646; 6656-6660

							at 10V exc					
34	INT LUMBAR Mx TORQUE (IN-LB)	DENTON 1914A	365	13-Mar-15	5.11 uv/in-lb at 10V exc	19-May-15	5.07 uv/in-lb at 10V exc	-0.8	.000511 mv/v/in-lb	FULL	3000 IN-LB	CASE 6 tests 6647-6655; 6661-6664
35	INT LUMBAR My TORQUE (IN-LB)	DENTON 1914A	310	14-Oct-14	5.20 uv/in-lb at 10V exc	06-May-15	5.11 uv/in-lb at 10V exc	-1.7	.000520 mv/v/in-lb	FULL	3000 IN-LB	CASE 1 tests 6636-6646; 6656-6660
35	INT LUMBAR My TORQUE (IN-LB)	DENTON 1914A	365	13-Mar-15	5.10 uv/in-lb at 10V exc	19-May-15	5.06 uv/in-lb at 10V exc	-0.8	.000510 mv/v/in-lb	FULL	3000 IN-LB	CASE 6 tests 6647-6655; 6661-6664
36	INT LUMBAR Mz TORQUE (IN-LB)	DENTON 1914A	310	14-Oct-14	8.70 uv/in-lb at 10V exc	06-May-15	8.57 uv/in-lb at 10V exc	-1.5	.000870 mv/v/in-lb	FULL	3000 IN-LB	CASE 1 tests 6636-6646; 6656-6660
36	INT LUMBAR Mz TORQUE (IN-LB)	DENTON 1914A	365	13-Mar-15	8.47 uv/in-lb at 10V exc	19-May-15	8.33 uv/in-lb at 10V exc	-1.7	.000847 mv/v/in-lb	FULL	3000 IN-LB	CASE 6 tests 6647-6655; 6661-6664
37	LEFT FEMUR X FORCE (LB)	DENTON 1914A	295	16-Dec-14	6.63 uv/lb at 10V exc	05-May-15	6.64 uv/lb at 10V exc	0.2	.000663 mv/v/lb	FULL	3000 LB	CASE 1 tests 6636-6646; 6656-6660
37	LEFT FEMUR X FORCE (LB)	DENTON 1914A	438	16-Dec-14	6.69 uv/lb at 10V exc	19-May-15	6.68 uv/lb at 10V exc	-0.2	.000669 mv/v/lb	FULL	3000 LB	CASE 6 tests 6647-6655; 6661-6664
38	LEFT FEMUR Y FORCE (LB)	DENTON 1914A	295	16-Dec-14	6.64 uv/lb at 10V exc	05-May-15	6.55 uv/lb at 10V exc	-1.3	.000664 mv/v/lb	FULL	3000 LB	CASE 1 tests 6636-6646; 6656-6660
38	LEFT FEMUR Y FORCE (LB)	DENTON 1914A	438	16-Dec-14	6.72 uv/lb at 10V exc	19-May-15	6.63 uv/lb at 10V exc	-1.3	.000672 mv/v/lb	FULL	3000 LB	CASE 6 tests 6647-6655; 6661-6664
39	LEFT FEMUR	DENTON 1914A	295	16-Dec-14	2.46 uv/lb at 10V exc	05-May-15	2.45 uv/lb at 10V exc	-0.4	.000246 mv/v/lb	FULL	5000 LB	CASE 1 tests 6636-6646; 6656-6660

	Z FORCE (LB)											
39	LEFT FEMUR Z FORCE (LB)	DENTON 1914A	438	16-Dec-14	2.80 uv/lb at 10V exc	19-May-15	2.80 uv/lb at 10V exc	0.0	.000280 mv/v/lb	FULL	5000 LB	CASE 6 tests 6647-6655; 6661-6664
40	LEFT FEMUR Mx TORQUE (IN-LB)	DENTON 1914A	295	16-Dec-14	5.15 uv/in-lb at 10V exc	05-May-15	5.11 uv/in-lb at 10V exc	-0.8	.000515 mv/v/in-lb	FULL	3000 IN-LB	CASE 1 tests 6636-6646; 6656-6660
40	LEFT FEMUR Mx TORQUE (IN-LB)	DENTON 1914A	438	16-Dec-14	5.30 uv/in-lb at 10V exc	19-May-15	5.24 uv/in-lb at 10V exc	-1.1	.000530 mv/v/in-lb	FULL	3000 IN-LB	CASE 6 tests 6647-6655; 6661-6664
41	LEFT FEMUR My TORQUE (IN-LB)	DENTON 1914A	295	16-Dec-14	5.14 uv/in/lb at 10V exc	05-May-15	5.09 uv/in-lb at 10V exc	-1.0	.000514 mv/v/in-lb	FULL	3000 IN-LB	CASE 1 tests 6636-6646; 6656-6660
41	LEFT FEMUR My TORQUE (IN-LB)	DENTON 1914A	438	16-Dec-14	5.23 uv/in-lb at 10V exc	19-May-15	5.20 uv/in-lb at 10V exc	-0.6	.000523 mv/v/in-lb	FULL	3000 IN-LB	CASE 6 tests 6647-6655; 6661-6664
42	LEFT FEMUR Mz TORQUE (IN-LB)	DENTON 1914A	295	16-Dec-14	8.59 uv/in-lb at 10V exc	05-May-15	8.45 uv/in-lb at 10V exc	-1.6	.000859 mv/v/in-lb	FULL	3000 IN-LB	CASE 1 tests 6636-6646; 6656-6660
42	LEFT FEMUR Mz TORQUE (IN-LB)	DENTON 1914A	438	16-Dec-14	8.77 uv/in-lb at 10V exc	19-May-15	8.57 uv/in-lb at 10V exc	-2.3	.000877 mv/v/in-lb	FULL	3000 IN-LB	CASE 6 tests 6647-6655; 6661-6664
43	RIGHT FEMUR X FORCE (LB)	DENTON 1914A	503	14-Oct-14	6.58 uv/lb at 10V exc	07-May-15	6.57 uv/lb at 10V exc	-0.2	.000658 mv/v/lb	FULL	3000 LB	CASE 1 tests 6636-6646; 6656-6660
43	RIGHT FEMUR X FORCE (LB)	DENTON 1914A	296	16-Dec-14	6.65 uv/lb at 10V exc	19-May-15	6.65 uv/in-lb at 10V exc	0.0	.000665 mv/v/lb	FULL	3000 LB	CASE 6 tests 6647-6655; 6661-6664
44	RIGHT FEMUR	DENTON 1914A	503	14-Oct-14	6.59 uv/lb at 10V exc	07-May-15	6.49 uv/lb at 10V exc	-1.5	.000659 mv/v/lb	FULL	3000 LB	CASE 1 tests 6636-6646; 6656-6660

	Y FORCE (LB)											
44	RIGHT FEMUR Y FORCE (LB)	DENTON 1914A	296	16-Dec-14	6.67 uv/lb at 10V exc	19-May-15	6.59 uv/lb at 10V exc	-1.2	.000667 mv/v/lb	FULL	3000 LB	CASE 6 tests 6647-6655; 6661-6664
45	RIGHT FEMUR Z FORCE (LB)	DENTON 1914A	503	14-Oct-14	2.71 uv/lb at 10V exc	07-May-15	2.69 uv/lb at 10V exc	-0.7	.000271 mv/v/lb	FULL	5000 LB	CASE 1 tests 6636-6646; 6656-6660
45	RIGHT FEMUR Z FORCE (LB)	DENTON 1914A	296	16-Dec-14	2.45 uv/lb at 10V 3exc	19-May-15	2.46 uv/lb at 10V exc	0.4	.000245 mv/v/lb	FULL	5000 LB	CASE 6 tests 6647-6655; 6661-6664
46	RIGHT FEMUR Mx TORQUE (IN-LB)	DENTON 1914A	503	14-Oct-14	5.16 uv/in/lb at 10V exc	07-May-15	5.08 uv/in-lb at 10V exc	-1.6	.000516 mv/v/in-lb	FULL	3000 IN-LB	CASE 1 tests 6636-6646; 6656-6660
46	RIGHT FEMUR Mx TORQUE (IN-LB)	DENTON 1914A	296	16-Dec-14	5.16 uv/in/lb at 10V exc	19-May-15	5.10 uv/in-lb at 10V exc	-1.2	.000516 mv/v/in-lb	FULL	3000 IN-LB	CASE 6 tests 6647-6655; 6661-6664
47	RIGHT FEMUR My TORQUE (IN-LB)	DENTON 1914A	503	14-Oct-14	5.14 uv/in/lb at 10V exc	07-May-15	5.05 uv/in-lb at 10V exc	-1.8	.000514 mv/v/in-lb	FULL	3000 IN-LB	CASE 1 tests 6636-6646; 6656-6660
47	RIGHT FEMUR My TORQUE (IN-LB)	DENTON 1914A	296	16-Dec-14	5.15 uv/in-lb at 10V exc	19-May-15	5.14 uv/in-lb at 10V exc	-0.2	.000515 mv/v/in-lb	FULL	3000 IN-LB	CASE 6 tests 6647-6655; 6661-6664
48	RIGHT FEMUR Mz TORQUE (IN-LB)	DENTON 1914A	503	14-Oct-14	8.51 uv/in/lb at 10V exc	07-May-15	8.35 uv/in-lb at 10V exc	-1.9	.000851 mv/v/in-lb	FULL	3000 IN-LB	CASE 1 tests 6636-6646; 6656-6660
48	RIGHT FEMUR Mz TORQUE (IN-LB)	DENTON 1914A	296	16-Dec-14	8.67 uv/in-lb at 10V exc	19-May-15	8.55 uv/in-lb at 10V exc	-1.4	.000867 mv/v/in-lb	FULL	3000 IN-LB	CASE 6 tests 6647-6655; 6661-6664

GLOSSARY

ABP	Aircrew Biodynamics and Protection
AETC	Air Education and Training Command
AFRL	Air Force Research Laboratory
AIRSAVE	Aircrew Integrated Recovery Survival Armor Vest and Equipment
DAS	Data Acquisition System
DoD	Department of Defense
DTS	Diversified Technical Systems
EFB	Electronic Flight Bag
FTW	Flying Training Wing
HPW	Human Performance Wing
JPATS	Joint Primary Aircraft Training System
LARD	Large Anthropometric Research Device
SAE	Society of Automotive Engineers
SUPT	Standardized Undergraduate Pilot Training
USAF	United States Air Force
VDT	Vertical Deceleration Tower
WPAFB	Wright Patterson Air Force Base

DEPARTMENT OF THE AIR FORCE
AIR FORCE RESEARCH LABORATORY
WRIGHT-PATTERSON AIR FORCE BASE OHIO 45433-7008

17 May 2017

MEMORANDUM FOR DTIC
8725 JOHN J. KINGMAN ROAD
FORT BELVOIR, VA 22060-6218

FROM: 711 HPW/OMA (STINFO)
2947 Fifth Street
Wright-Patterson AFB, OH 45433-7913

SUBJECT: Request to Change the Distribution Statement on a Technical Report

This memo documents the requirement for DTIC to change the distribution statement on the following technical report from distribution statement B to A.

AD Number: ADB410732
Publication number: AFRL-RH-WP-TR-2015-0041
Title: Biodynamic Assessment of Pilot Knee-Board Configurations During Simulated T-38 Catapult Acceleration

Reason for request: The technology that was evaluated is not currently the state-of-the-art in terms of what the aircrew are looking at using for electronic kneeboard configurations, and this is due to our assessment of that now "older" technology. My recommendation is to have this document status changed from Distribution B, Distribution A.

Donald Denio

DONALD DENIO
STINFO Officer
711th Human Performance Wing